



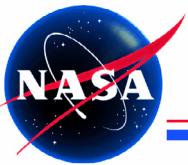
# **IKONOS-based Simulations of Landsat 7 VNIR Data: Comparison with Actual, Coincident Images**

Slawomir Blonski

Lockheed Martin Space Operations  
Commercial Remote Sensing Program  
NASA Stennis Space Center

March 19 - 21, 2001

phone: (228) 688-1944  
e-mail: [sblonski@ssc.nasa.gov](mailto:sblonski@ssc.nasa.gov)



# Contributors

Stennis Space Center

Robert Ryan  
Mary Pagnutti  
Charles Smith

LMSO, Stennis  
LMSO, Stennis  
LMSO, Stennis

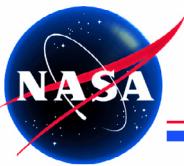
Vicki Zanoni  
Tom Stanley

NASA, Stennis  
NASA, Stennis

Robert Schowengerdt  
Stephen Schiller

Univ. of Arizona  
South Dakota State Univ.

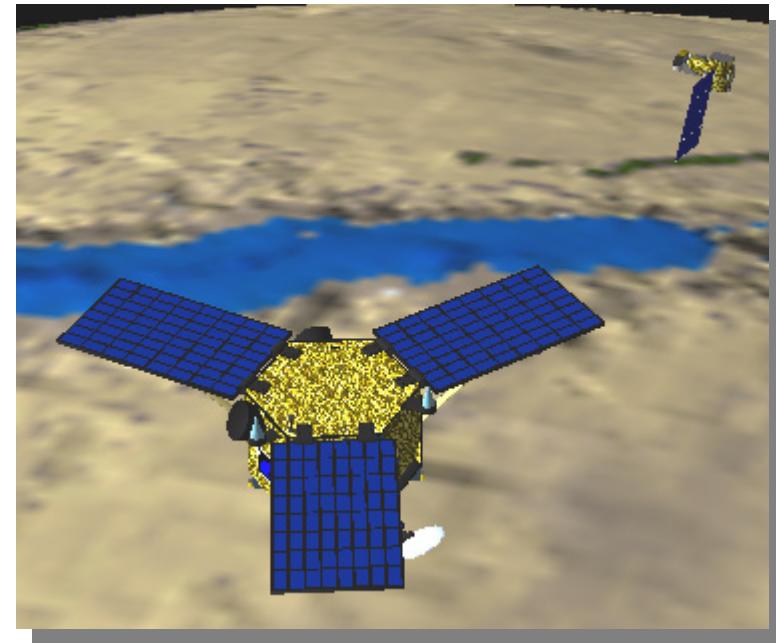




# IKONOS V&V: Landsat 7 Simulations

Stennis Space Center

- IKONOS images were used to simulate four VNIR bands of Landsat 7 level 1G images (similar processing level: radiometric correction, georeferenced with cubic-convolution resampling, UTM projection)
- In year 2000, 92% of Landsat 7 images distributed by USGS EROS Data Center were on the level 1G
- Simulations validated by comparing results with actual coincident Landsat 7 images
- Results provide insights on radiometric calibration, spatial resolution, and geolocation accuracy of the image products

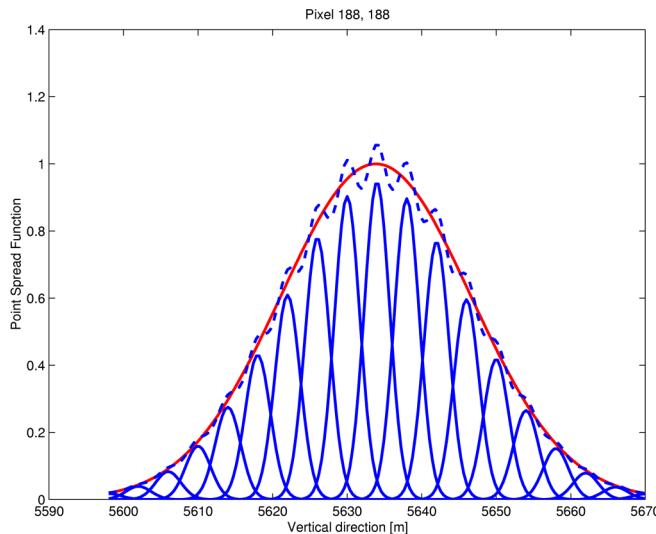


December 14, 2000  
Distance of 35 km

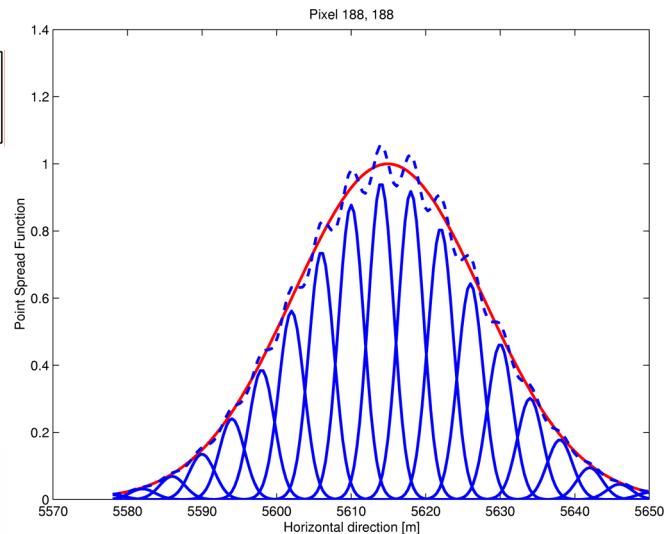


# Simulation Algorithm: PSF Synthesis

Stennis Space Center

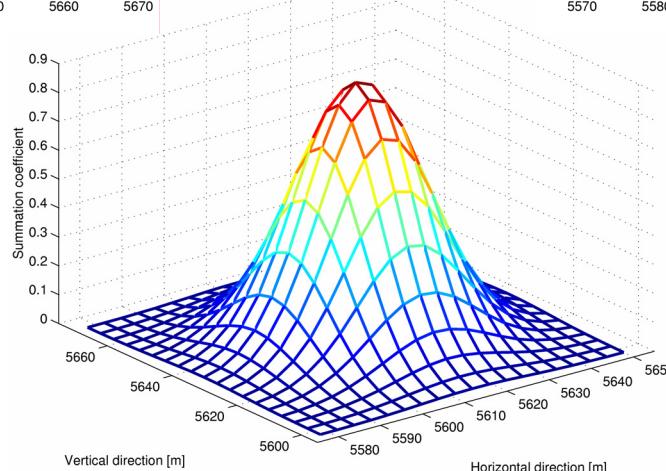


Pixel 188, 188  
— actual Landsat 7 PSF  
— IKONOS PSF  
- - - simulated Landsat 7 PSF



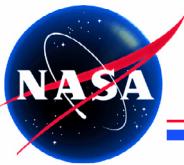
For each spectral band, the Landsat 7 image ( $I'$ ) is simulated by linear combination of the IKONOS image ( $I$ ) pixels:

$$I'_{kl} = \frac{\sum_i \sum_j c_{ijkl} I_{ij}}{\sum_i \sum_j c_{ijkl}}$$



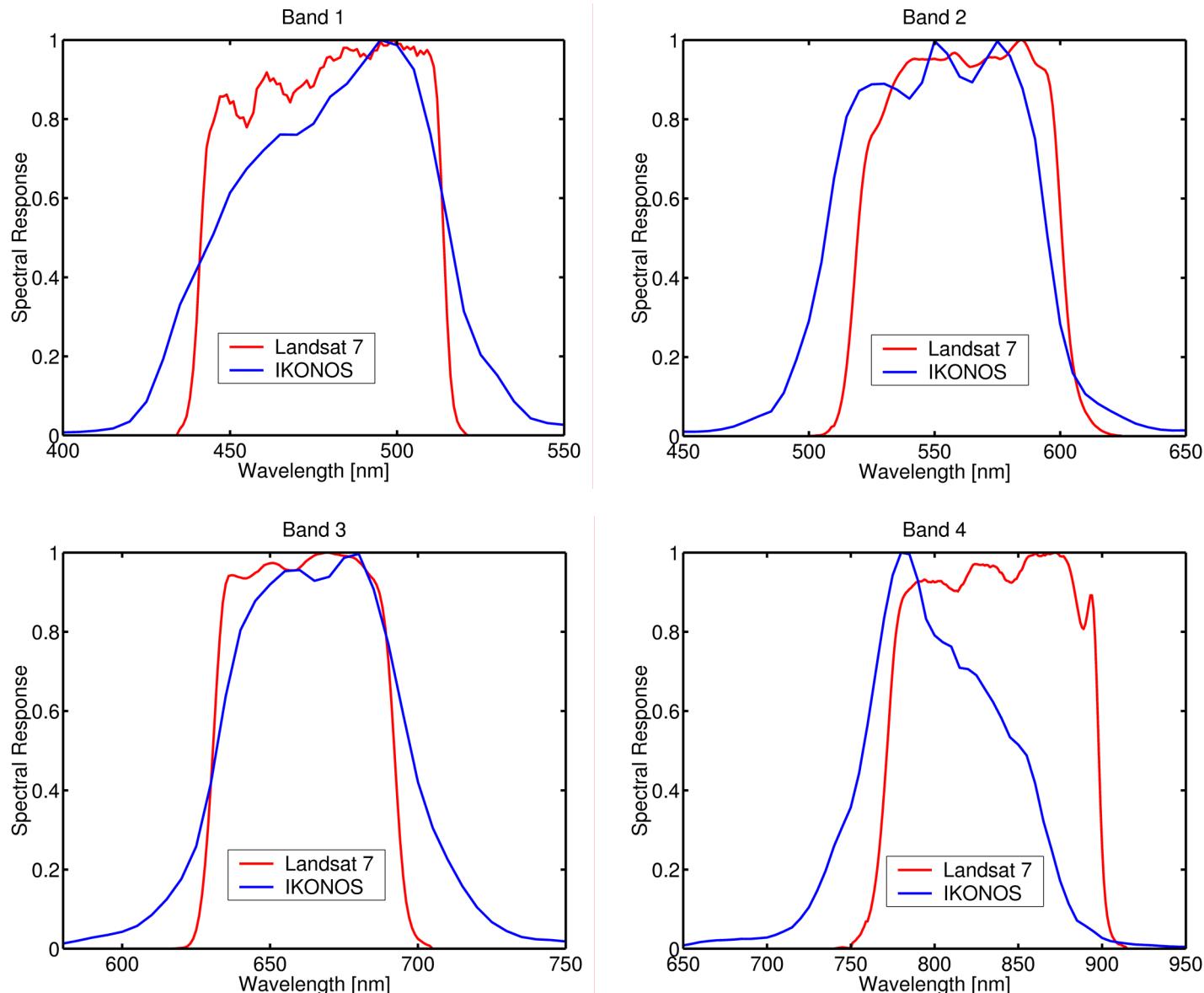
The coefficients  $c_{ijkl}$  are found independently for each Landsat 7 pixel by solving (in the least squares sense) for a given set of points  $(x, y)$  the following equation which expresses an effective point spread function (PSF') of the Landsat 7 image as a linear combination of the IKONOS image PSF's:

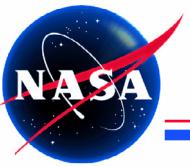
$$\text{PSF}'(x - x_l, y - y_k) = \sum_i \sum_j c_{ijkl} \text{PSF}(x - x_j, y - y_i)$$



# Comparison of Spectral Response

Stennis Space Center



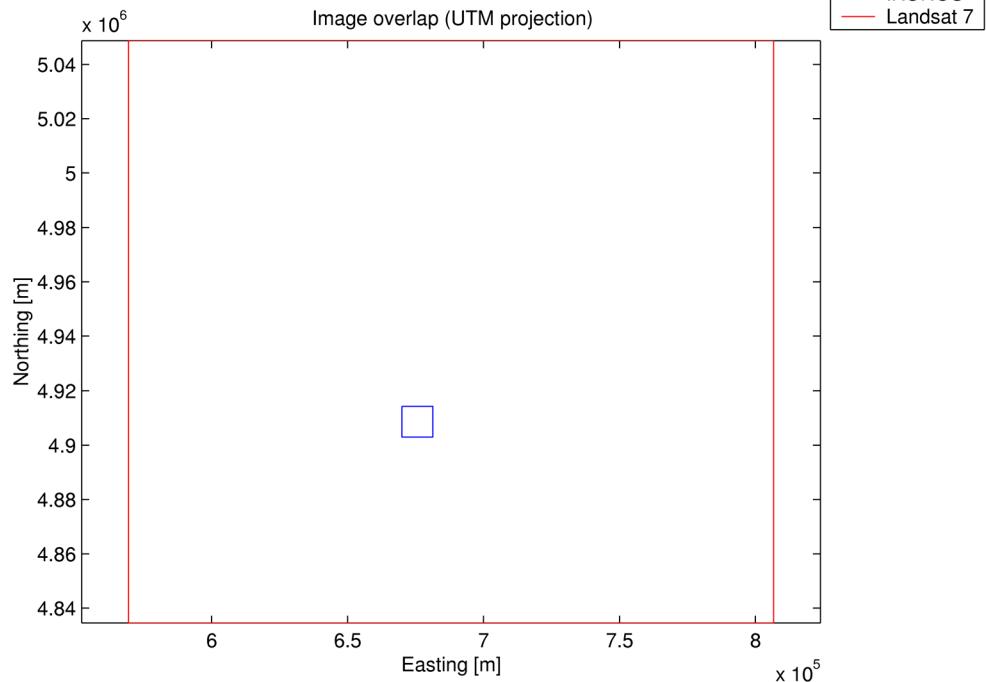
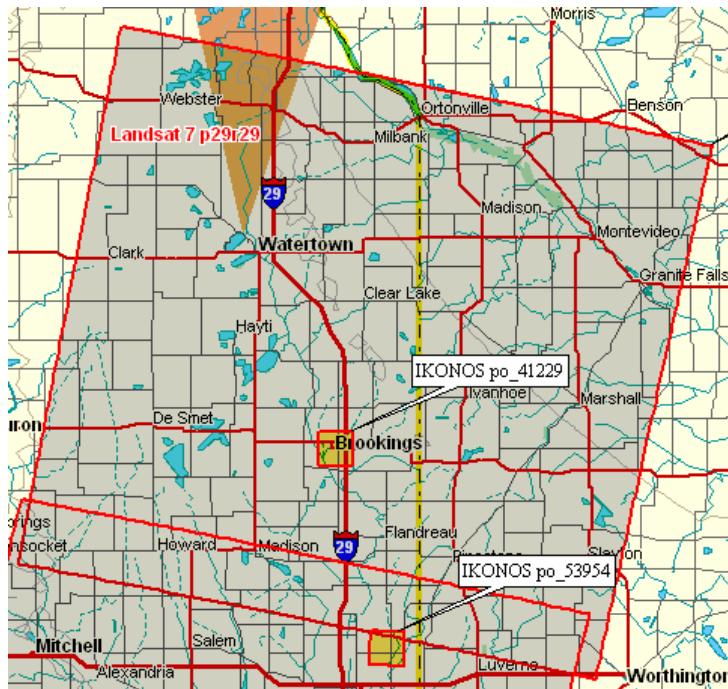


# Image Overlap: Brookings, SD

Stennis Space Center

Images acquired on June 30, 2000

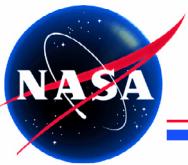
- IKONOS  
po\_41229 17:12 UTC 4 m GSD
- Landsat 7  
p29r29 17:03 UTC 30 m GSD



Both image products in map orientation (north up)

## Geolocation difference

- |         |       |                     |
|---------|-------|---------------------|
| Band 1: | 113 m | [ -11.25, -112.50 ] |
| Band 2: | 109 m | [ -11.25, -108.75 ] |
| Band 3: | 109 m | [ -11.25, -108.75 ] |
| Band 4: | 109 m | [ -7.50, -108.75 ]  |



# Image Comparison: South Dakota

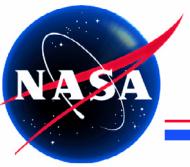
Stennis Space Center



Actual Landsat 7 image



Simulated Landsat 7 image

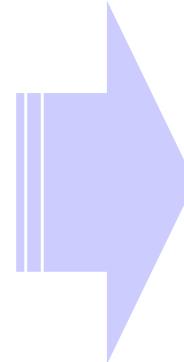


# Image Detail Comparison

Stennis Space Center



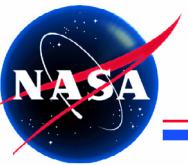
IKONOS image



Simulated Landsat 7 image



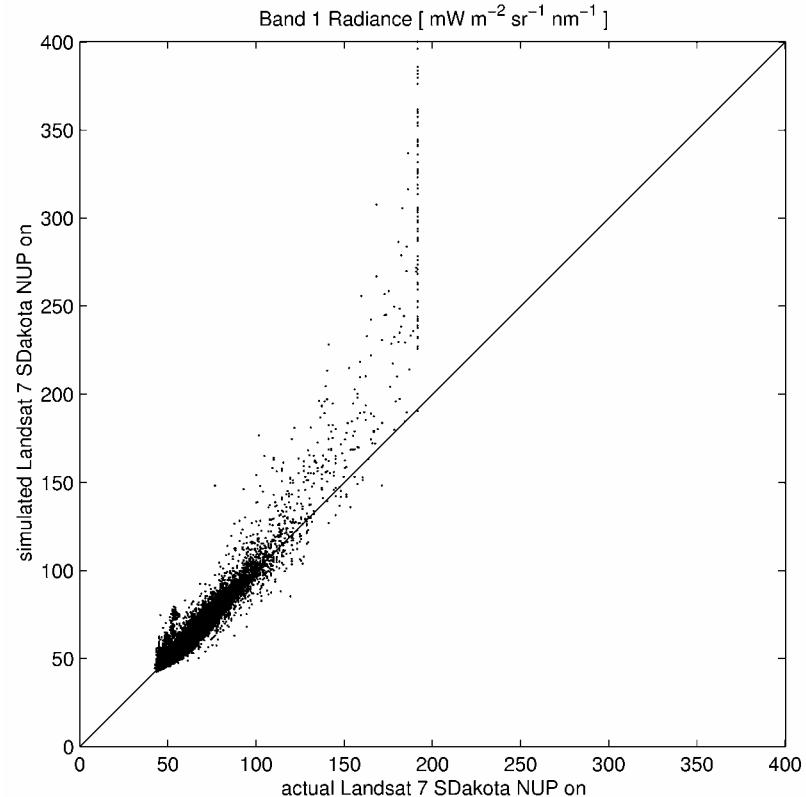
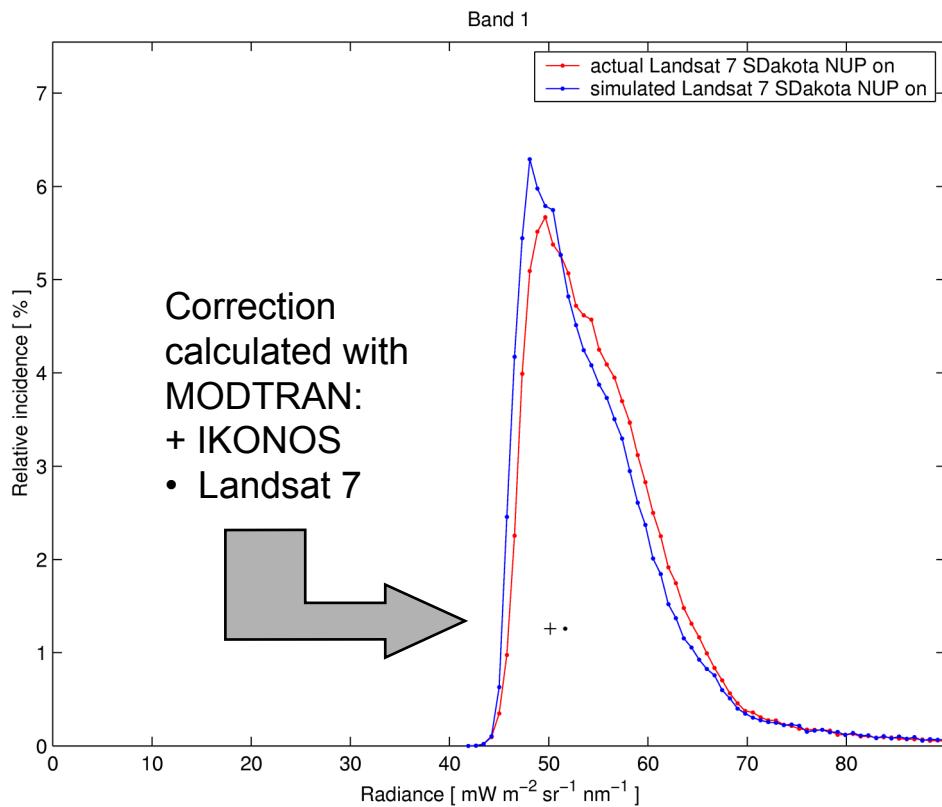
Actual Landsat 7 image



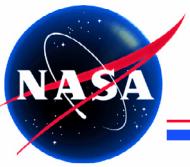
# Radiometric Comparison: Band 1

Stennis Space Center

- Based on updated IKONOS radiometric calibration coefficients:  
$$L = DN / 630 \text{ sr}\cdot\text{cm}^2\cdot\text{mW}^{-1}$$
- Differences: acquisition time (solar angle), collection geometry (azimuth and elevation angle), spectral response



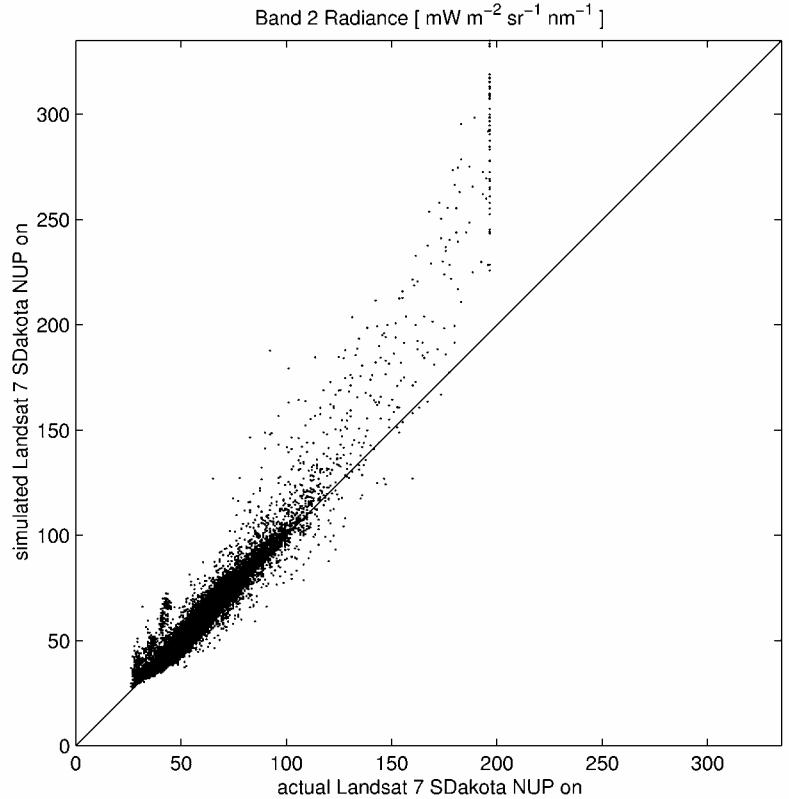
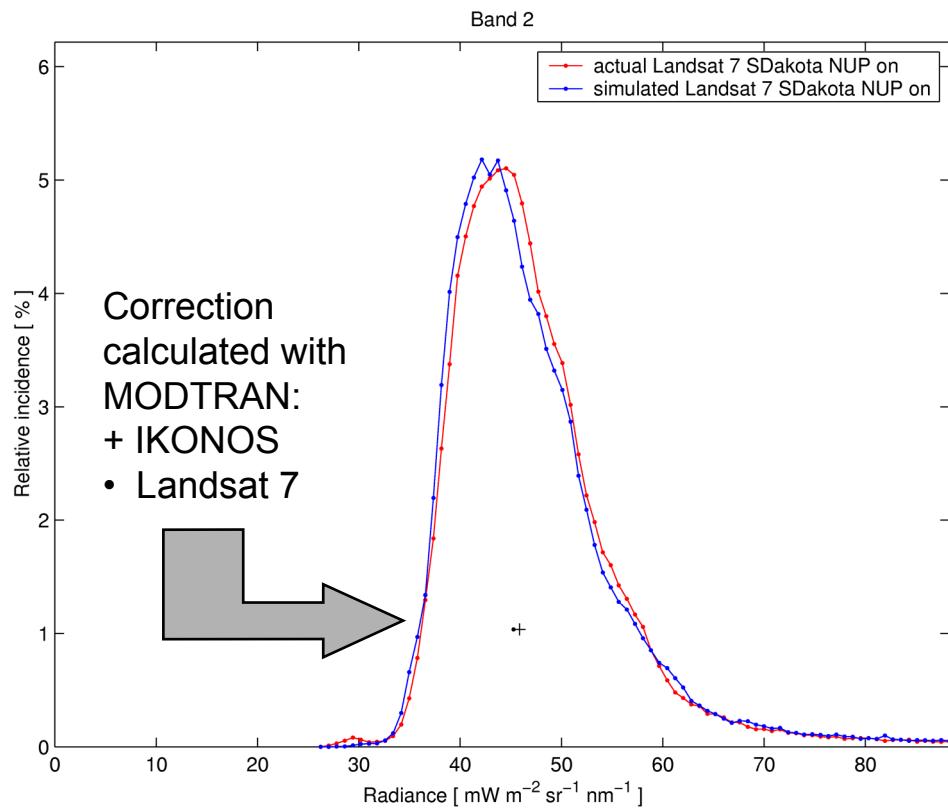
- Dispersion of points on the scatter plot due to noise and geolocation differences
- Presence of saturated Landsat 7 pixels
- Nonlinear response of Landsat 7 at higher radiance most likely due to saturation of the original L7 pixels (before resampling to L1G)



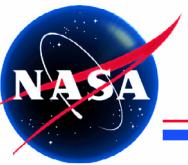
# Radiometric Comparison: Band 2

Stennis Space Center

- Based on updated IKONOS radiometric calibration coefficients:  
 $L = DN / 650 \text{ sr}\cdot\text{cm}^2\cdot\text{mW}^{-1}$
- Differences: acquisition time (solar angle), collection geometry (azimuth and elevation angle), spectral response



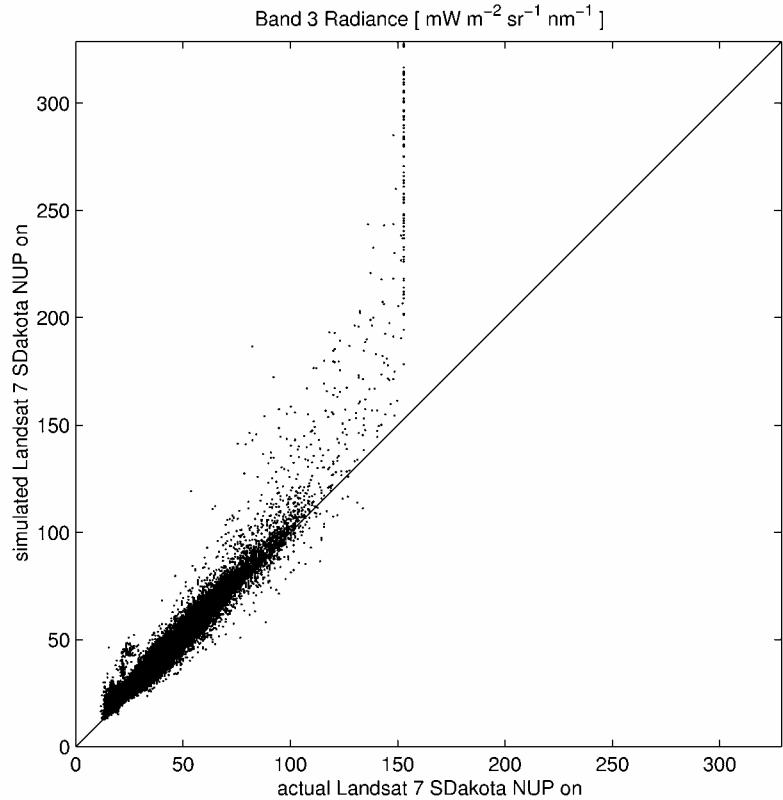
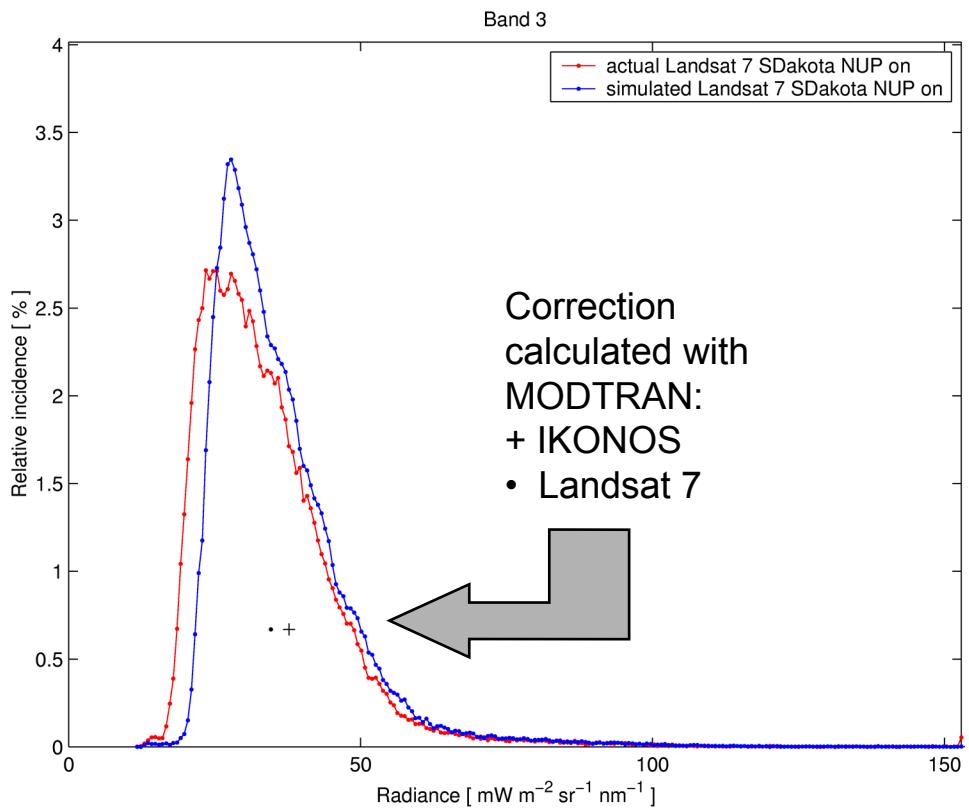
- Dispersion of points on the scatter plot due to noise and geolocation differences
- Presence of saturated Landsat 7 pixels
- Nonlinear response of Landsat 7 at higher radiance most likely due to saturation of the original L7 pixels (before resampling to L1G)



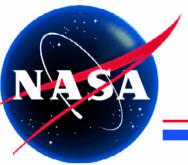
# Radiometric Comparison: Band 3

Stennis Space Center

- Based on updated IKONOS radiometric calibration coefficients:  
 $L = DN / 840 \text{ sr}\cdot\text{cm}^2\cdot\text{mW}^{-1}$
- Differences: acquisition time (solar angle), collection geometry (azimuth and elevation angle), spectral response



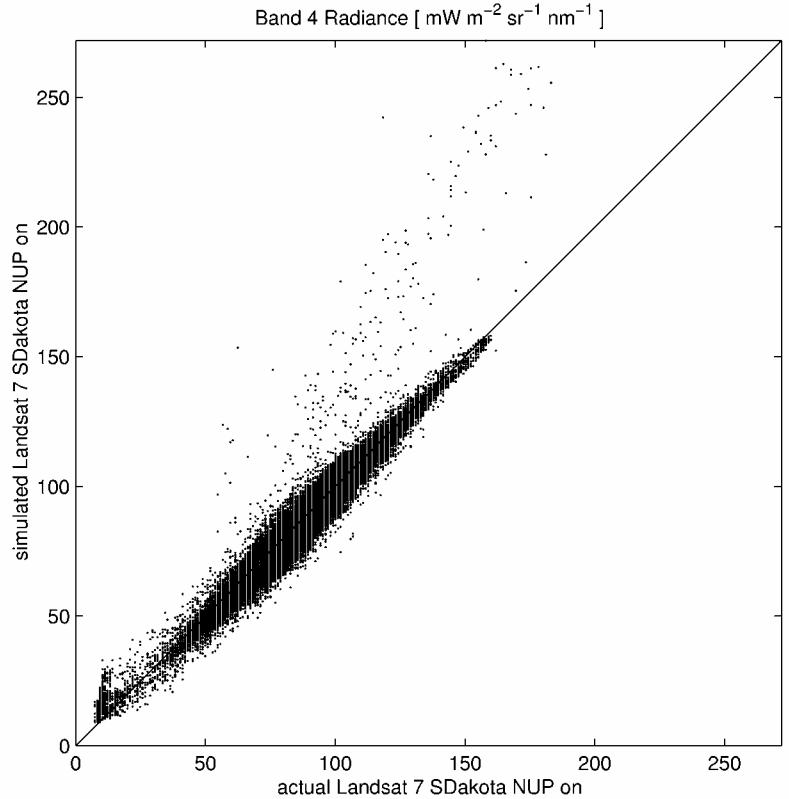
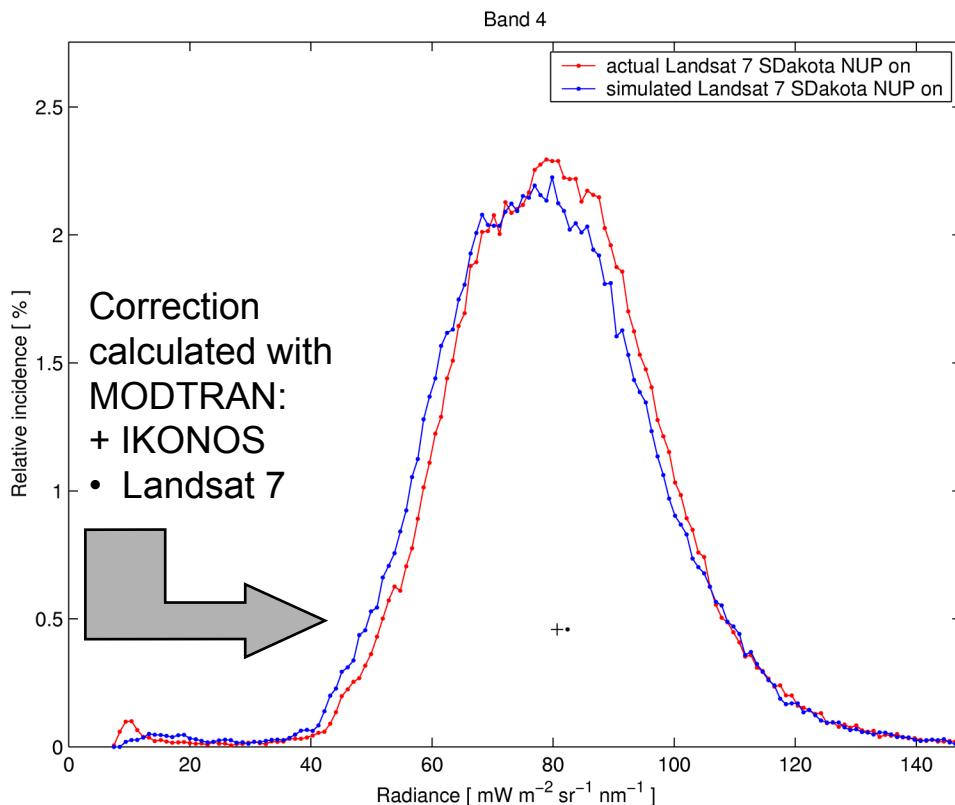
- Dispersion of points on the scatter plot due to noise and geolocation differences
- Presence of saturated Landsat 7 pixels
- Nonlinear response of Landsat 7 at higher radiance most likely due to saturation of the original L7 pixels (before resampling to L1G)



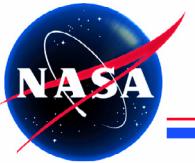
# Radiometric Comparison: Band 4

Stennis Space Center

- Based on updated IKONOS radiometric calibration coefficients:  
 $L = DN / 750 \text{ sr}\cdot\text{cm}^2\cdot\text{mW}^{-1}$
- Differences: acquisition time (solar angle), collection geometry (azimuth and elevation angle), spectral response



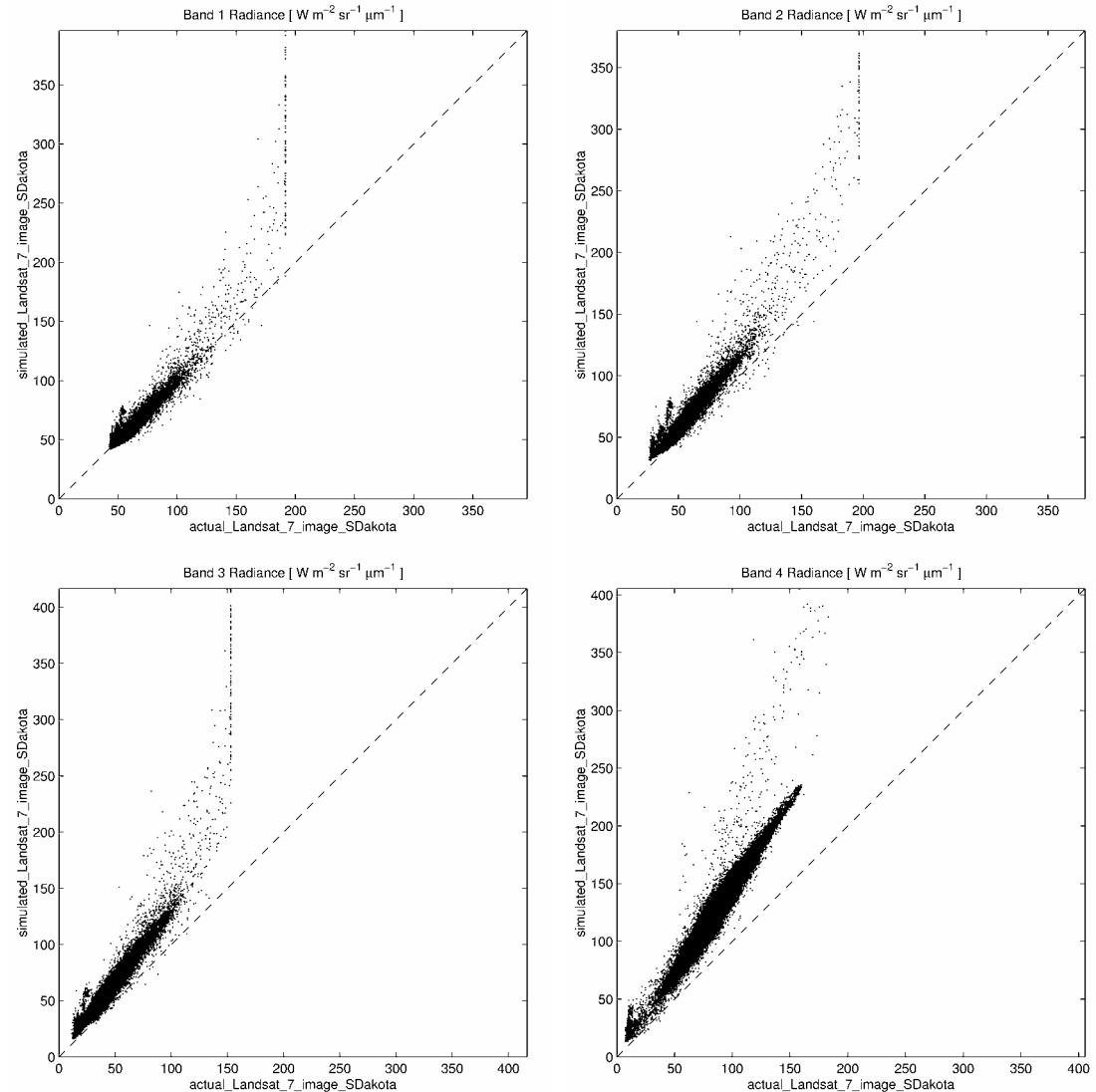
- Dispersion of points on the scatter plot due to noise and geolocation differences
- Nonlinear response of Landsat 7 at higher radiance most likely due to saturation of the original L7 pixels (before resampling to L1G)

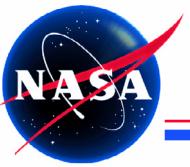


# Sensitivity to Radiometric Calibration

Stennis Space Center

Use of initial IKONOS radiometric calibration coefficients result in distorted scatter plots for bands 2, 3, and 4



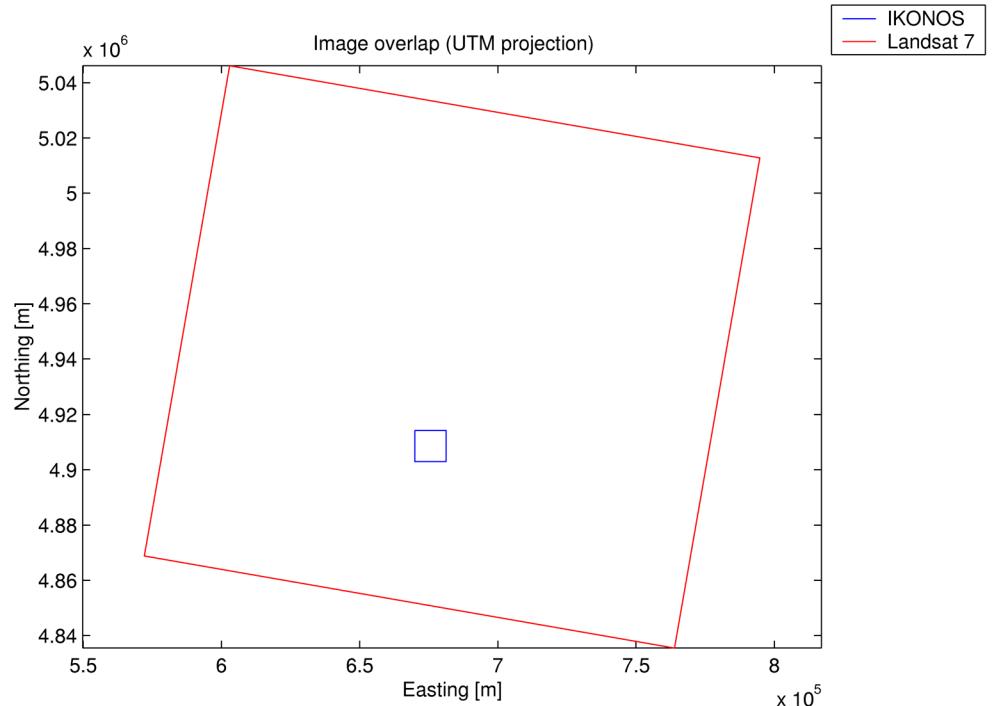


# Different Image Orientation

Stennis Space Center

The simulations were also conducted for images with different orientation:

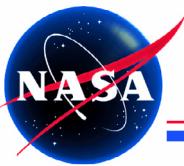
- IKONOS  
po\_41229 17:12 UTC  
4 m GSD  
map (north up) orientation
- Landsat 7  
p29r29 17:03 UTC  
28.5 m GSD  
nominal (satellite)  
orientation



## Geolocation difference

- Band 1: 168 m [-14.66, -167.40]  
Band 2: 168 m [-14.66, -167.40]  
Band 3: 168 m [-14.66, -167.40]  
Band 4: 168 m [-14.66, -167.40]

*Geolocation difference is still within the limits given by the geometric accuracy of Landsat 7 level 1G and IKONOS standard original image products (250 m)*

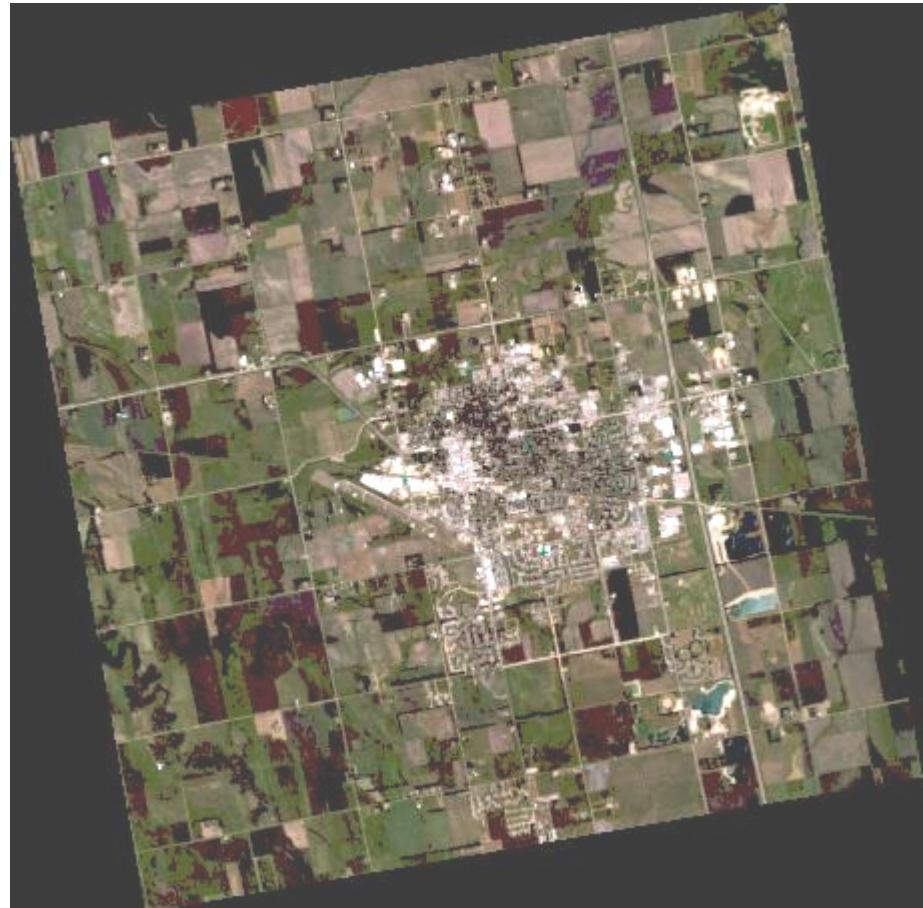


# Image Comparison: Different Orientation

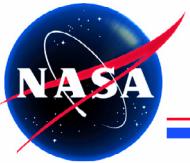
Stennis Space Center



Actual Landsat 7 image



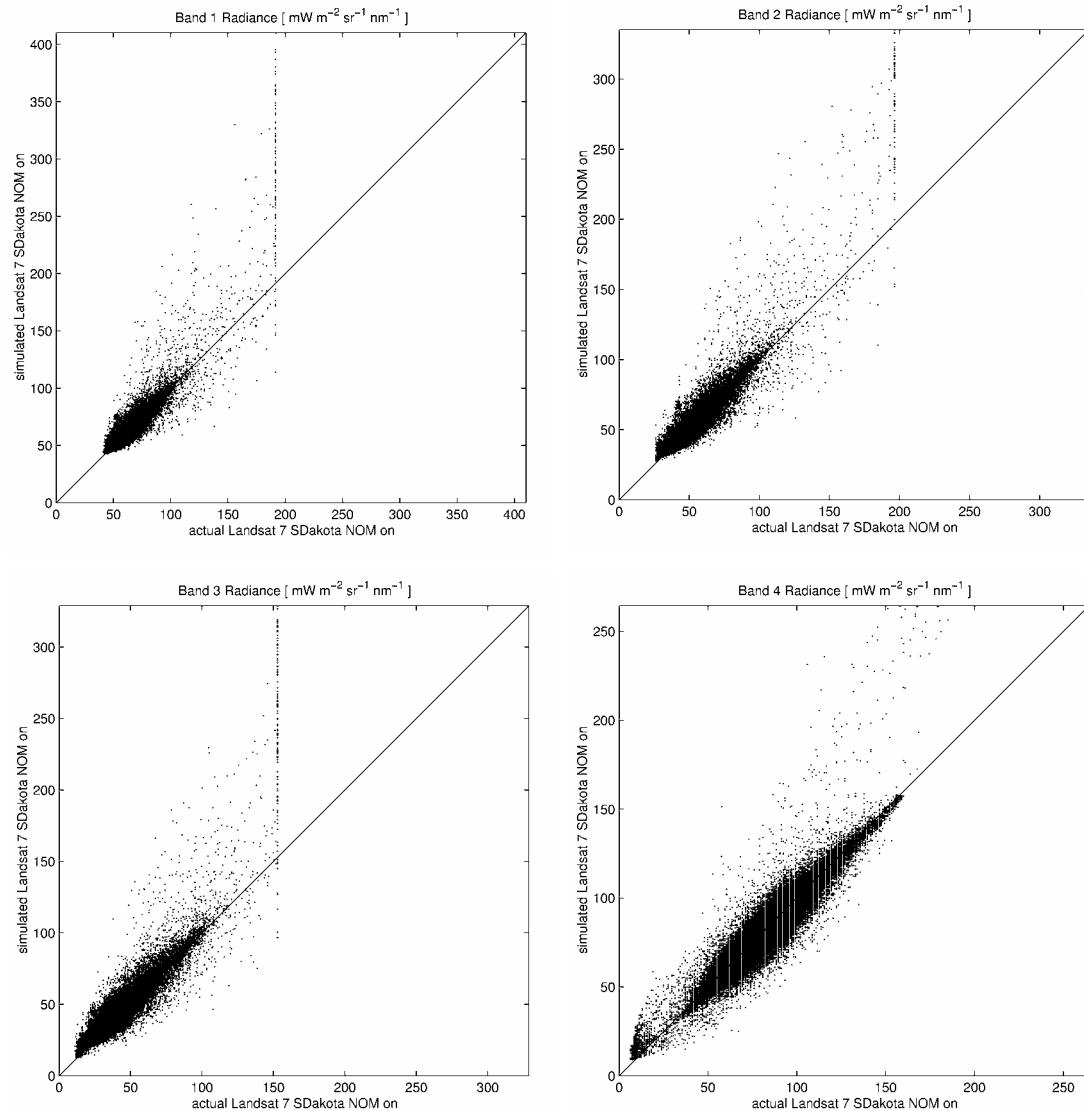
Simulated Landsat 7 image

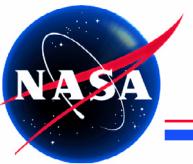


# Radiometric Comparison: Orientation

Stennis Space Center

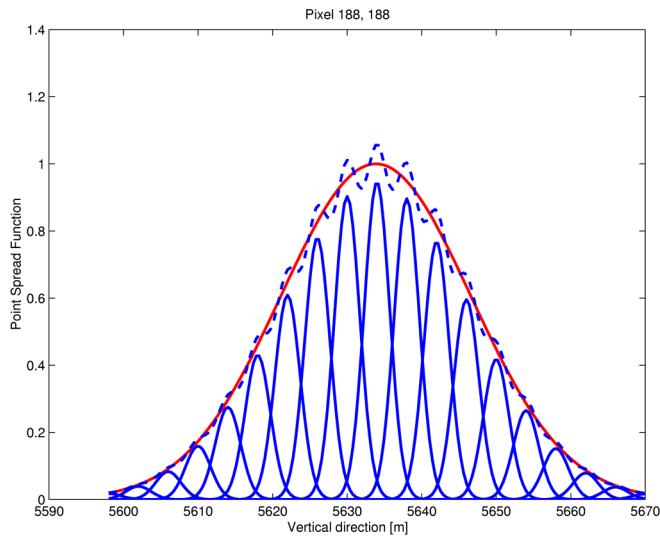
For the case when the input IKONOS image has a different orientation than the output Landsat 7 image, the scatter plots are more dispersed than in the case of images with the same orientation



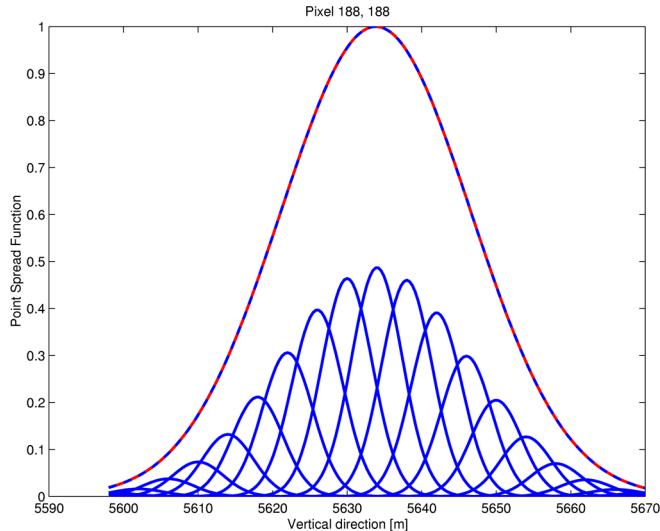
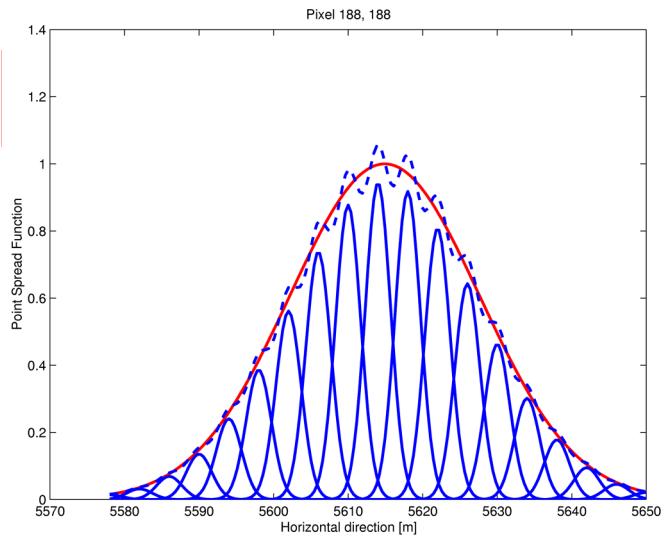


# Effect of Spatial Resolution

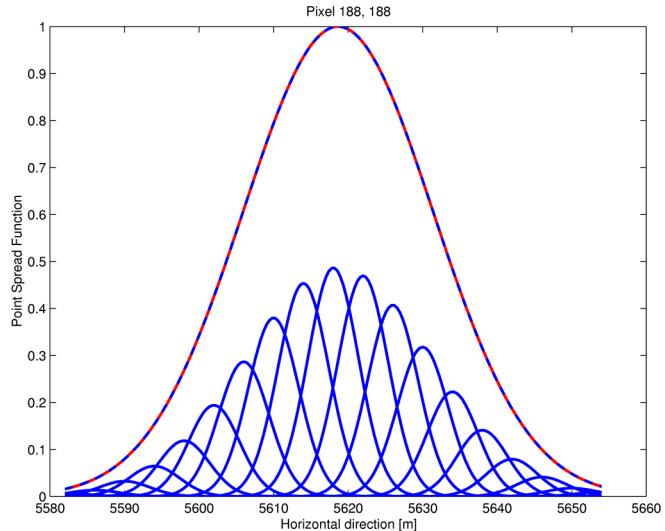
Stennis Space Center

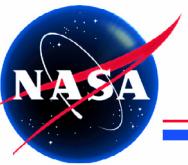


IKONOS  
po\_41229  
MTFC on  
FWHM = 1 GSD



IKONOS  
po\_53177  
MTFC off  
FWHM = 2 GSD



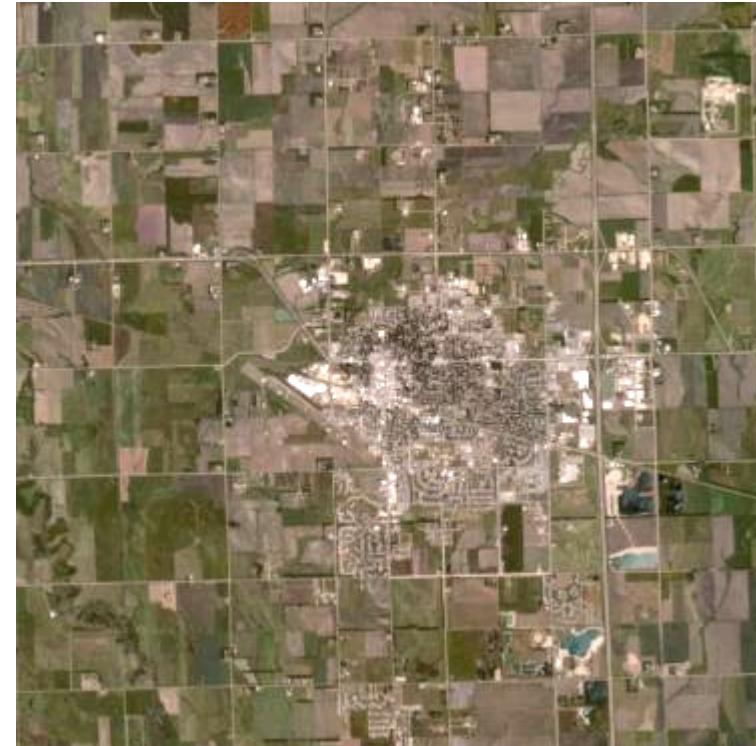


# Image Comparison: MTFC On / Off

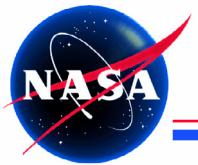
Stennis Space Center



Simulated Landsat 7 image created from the IKONOS image processed with the MTF compensation



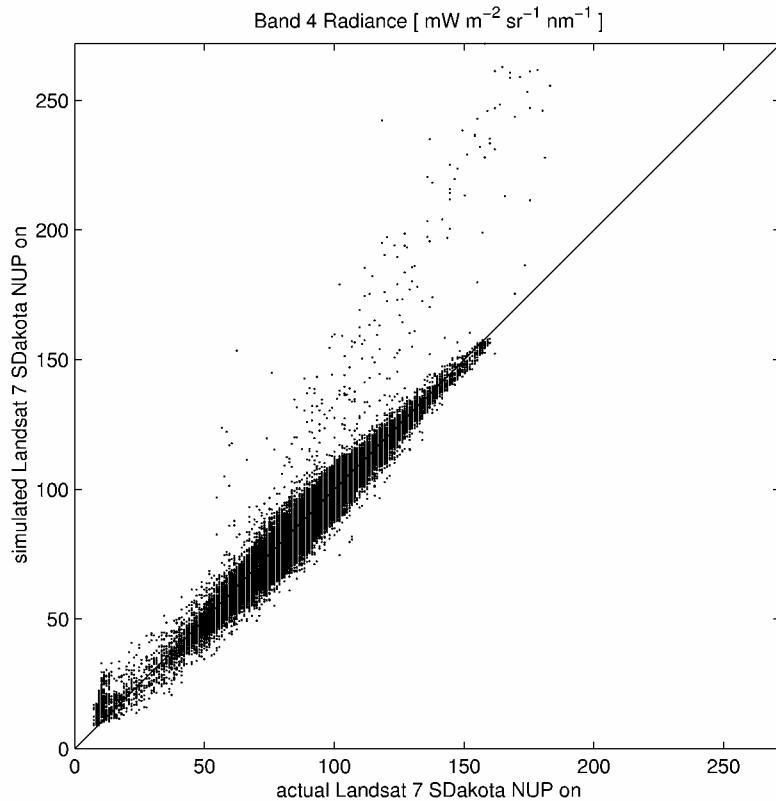
Simulated Landsat 7 image created from the IKONOS image processed without the MTF compensation



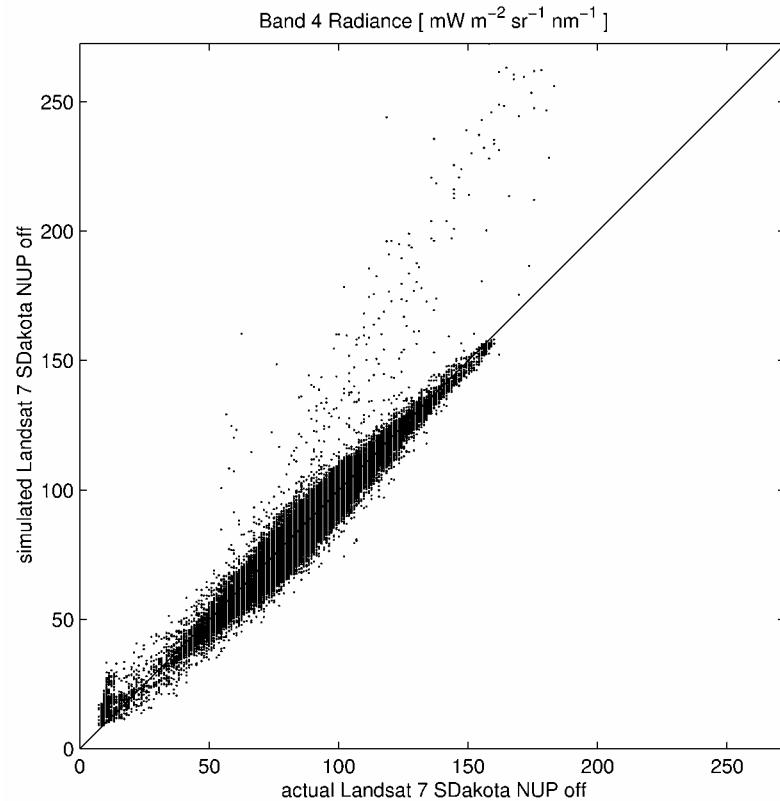
# Radiometric Comparison: MTFC On / Off

Stennis Space Center

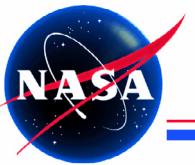
Band 4



MTFC on



MTFC off

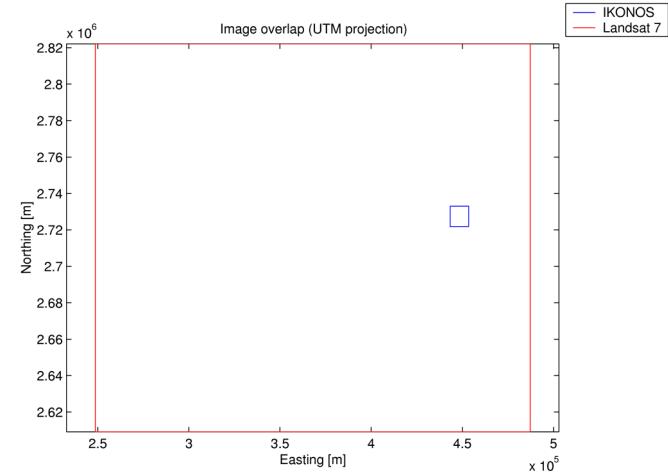
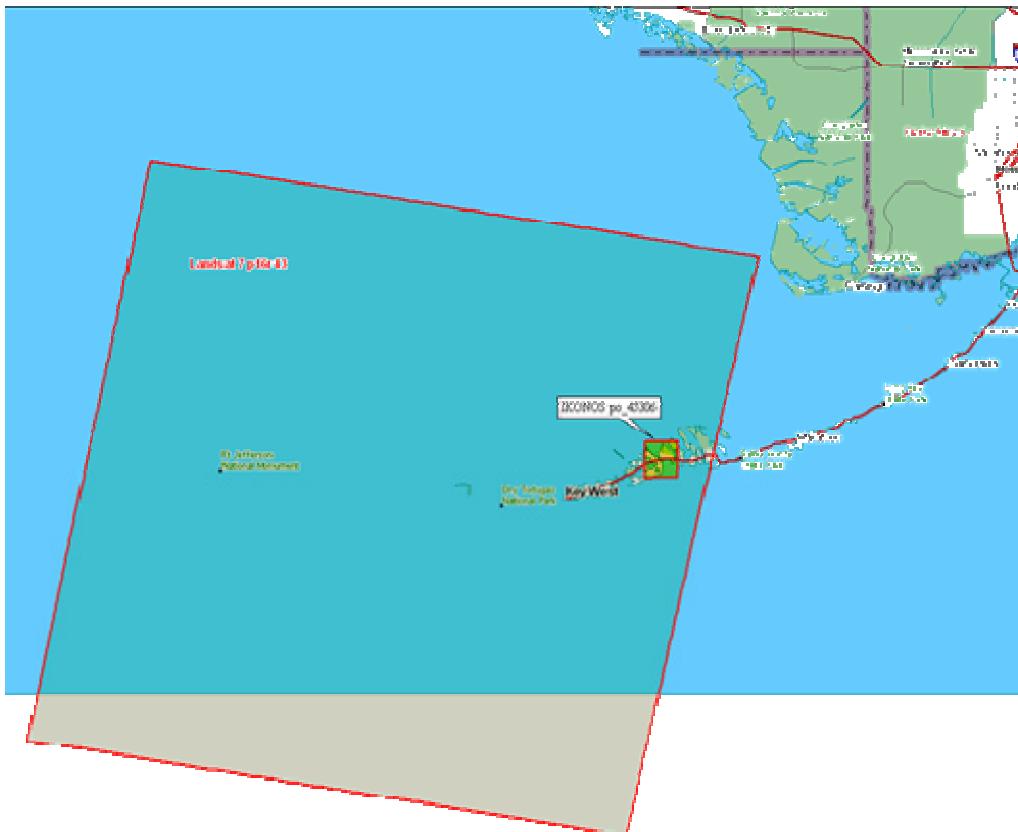


# Image Overlap: Florida

Stennis Space Center

Images acquired on September 7, 2000

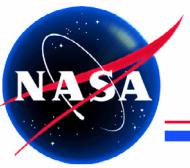
- IKONOS  
po\_45306 15:56 UTC 4 m GSD
- Landsat 7  
p16r43 15:47 UTC 30 m GSD



Both image products in map  
(north up) orientation

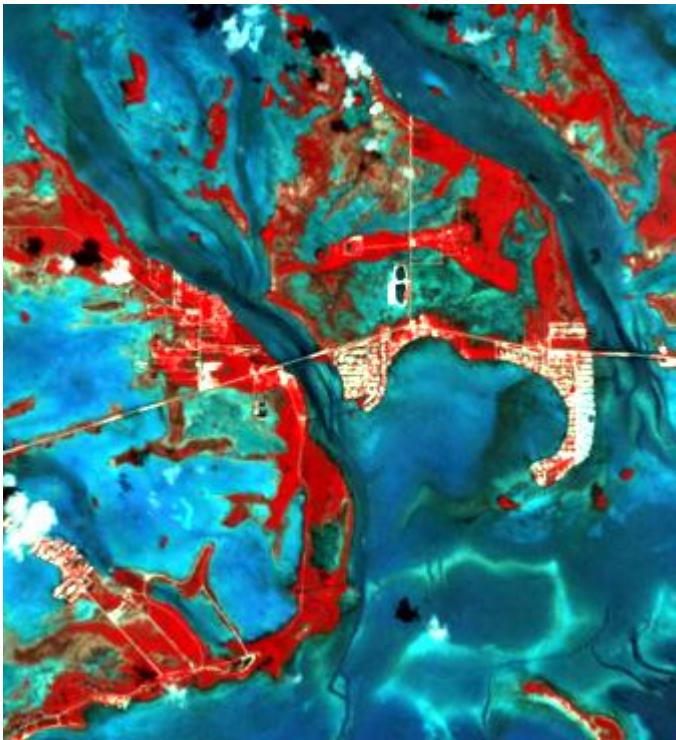
## Geolocation difference

- Band 1: 0 m
- Band 2: 0 m
- Band 3: 0 m
- Band 4: 0 m

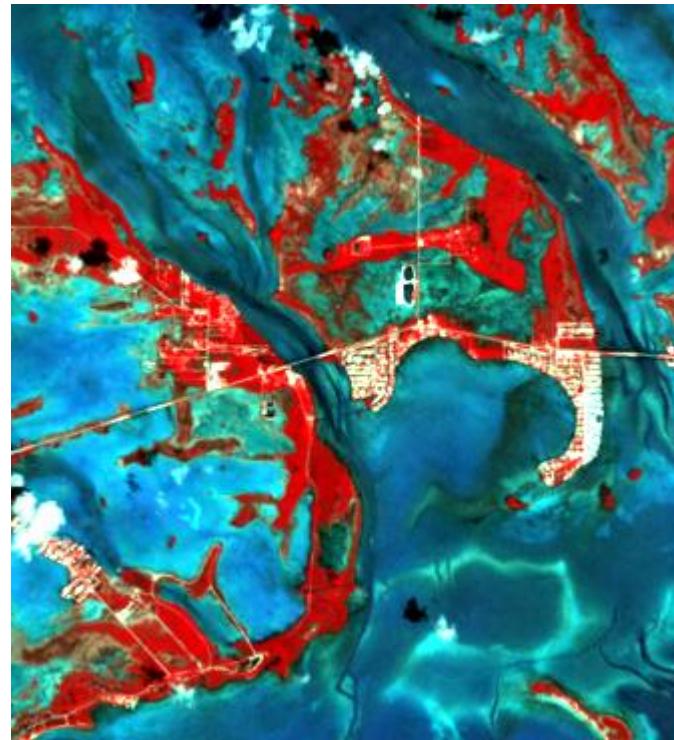


# Image Comparison: Florida

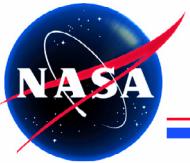
Stennis Space Center



Actual Landsat 7 image



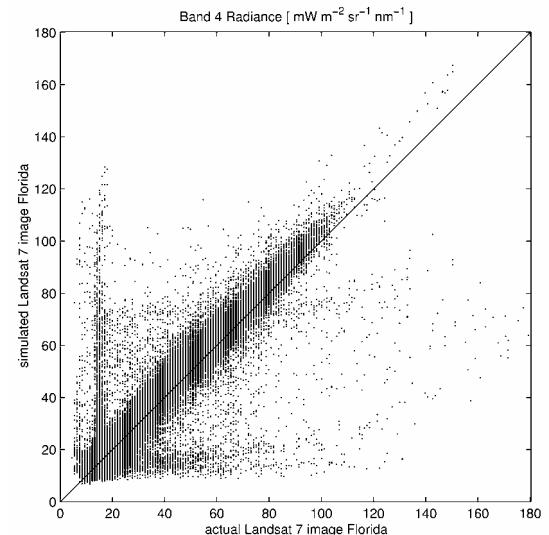
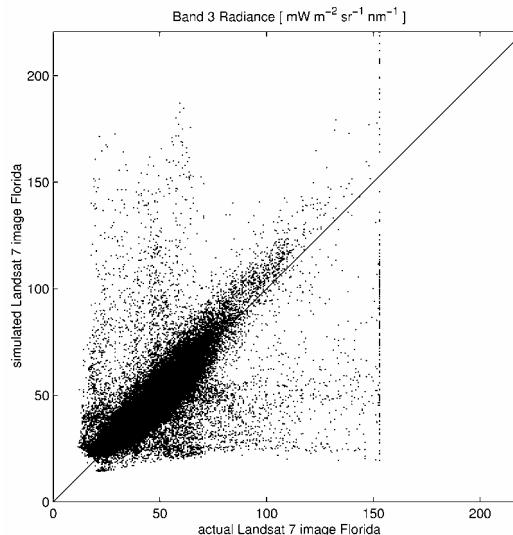
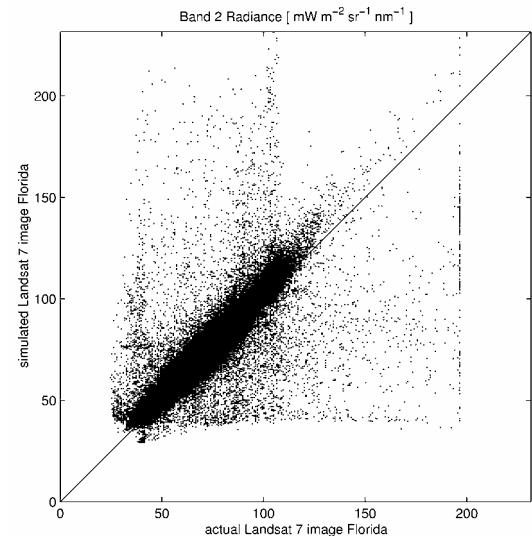
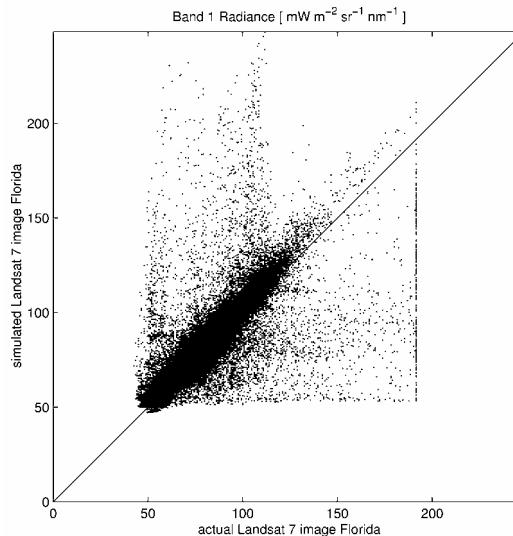
Simulated Landsat 7 image

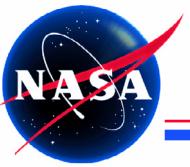


# Radiometric Comparison: Florida

Stennis Space Center

Orthogonal streaks are due to development and movement of clouds during the time between acquisitions of the two images



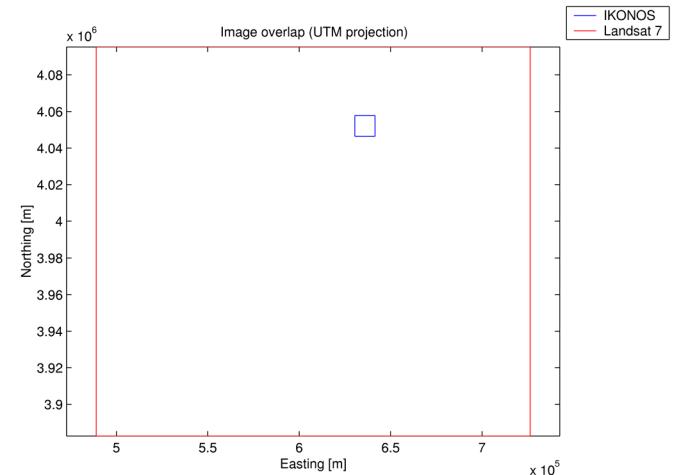
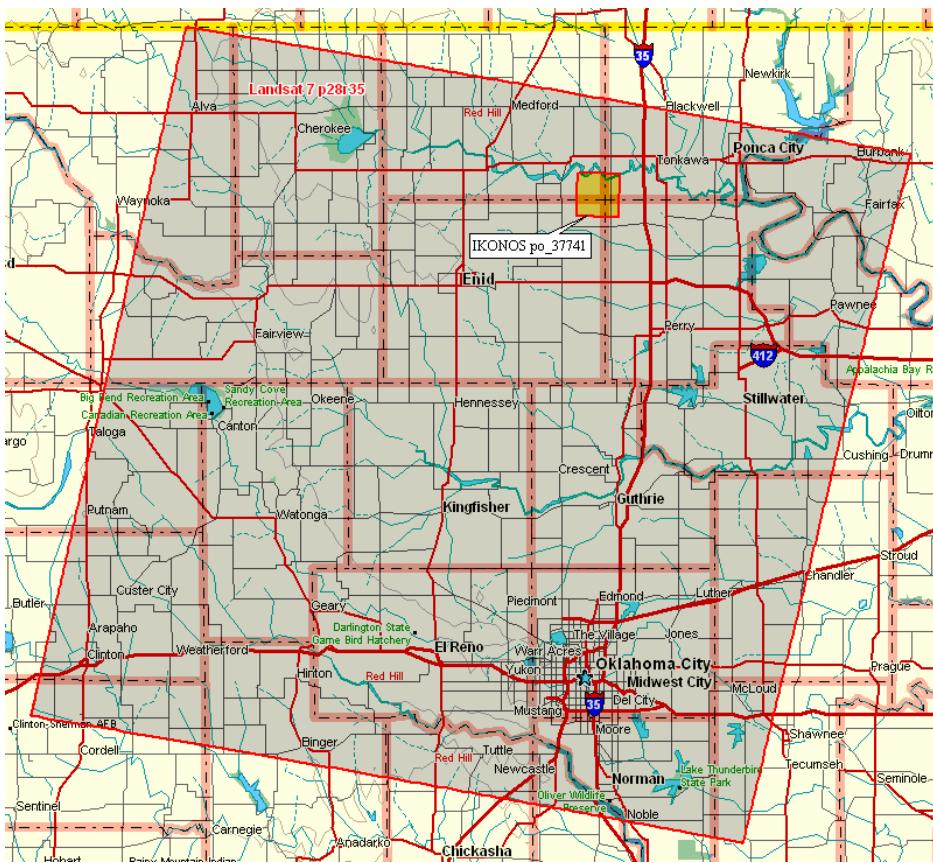


# Image Overlap: Oklahoma

Stennis Space Center

Images acquired on May 22, 2000

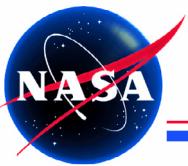
- IKONOS  
po\_37741 16:52 UTC 4 m GSD
- Landsat 7  
p28r35 16:59 UTC 30 m GSD



Both image products in map  
(north up) orientation

## Geolocation difference

- Band 1: 0 m
- Band 2: 0 m
- Band 3: 0 m
- Band 4: 0 m



# Image Comparison: Oklahoma

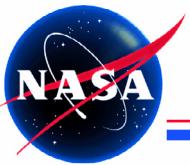
Stennis Space Center



Actual Landsat 7 image



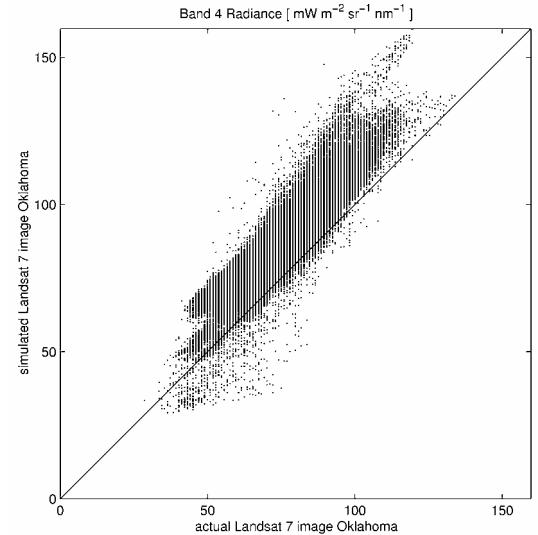
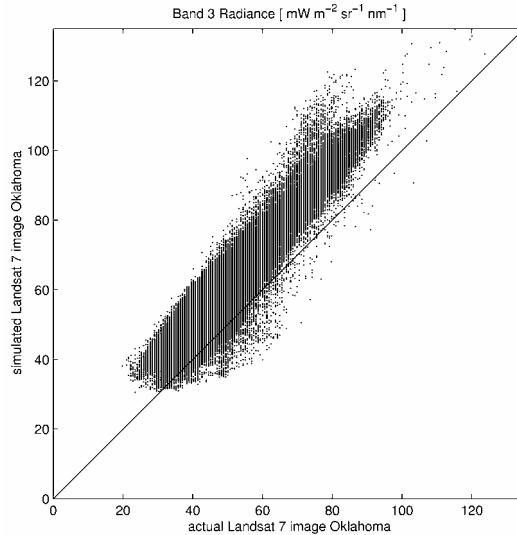
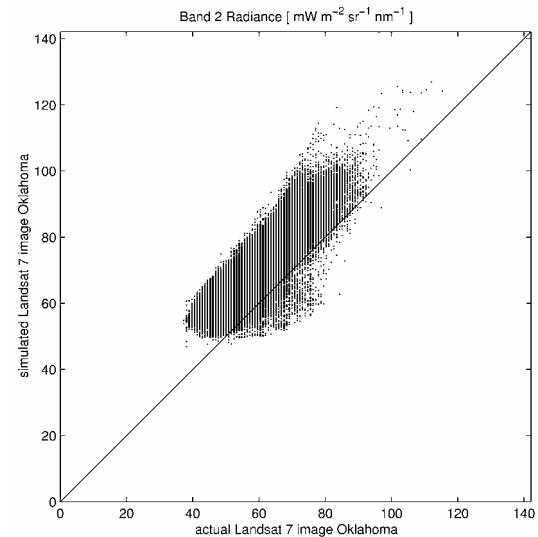
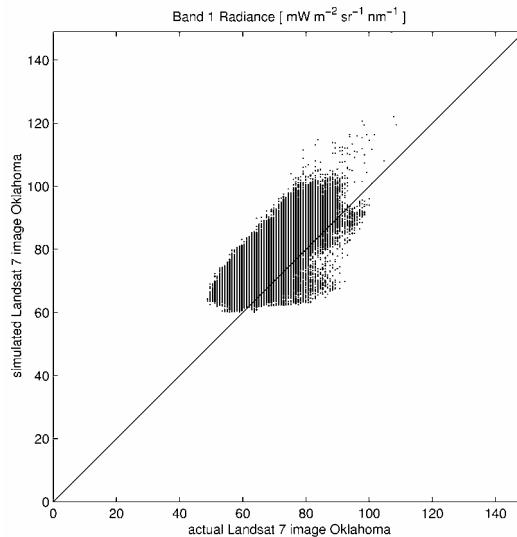
Simulated Landsat 7 image

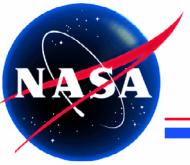


# Radiometric Comparison: Oklahoma

Stennis Space Center

Difference in atmospheric conditions (high cirrus clouds) resulted in attenuation of Landsat 7 at-sensor radiance and increased scattering



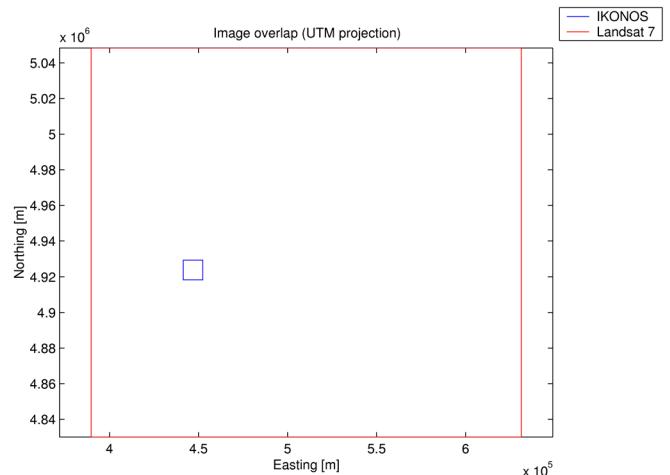
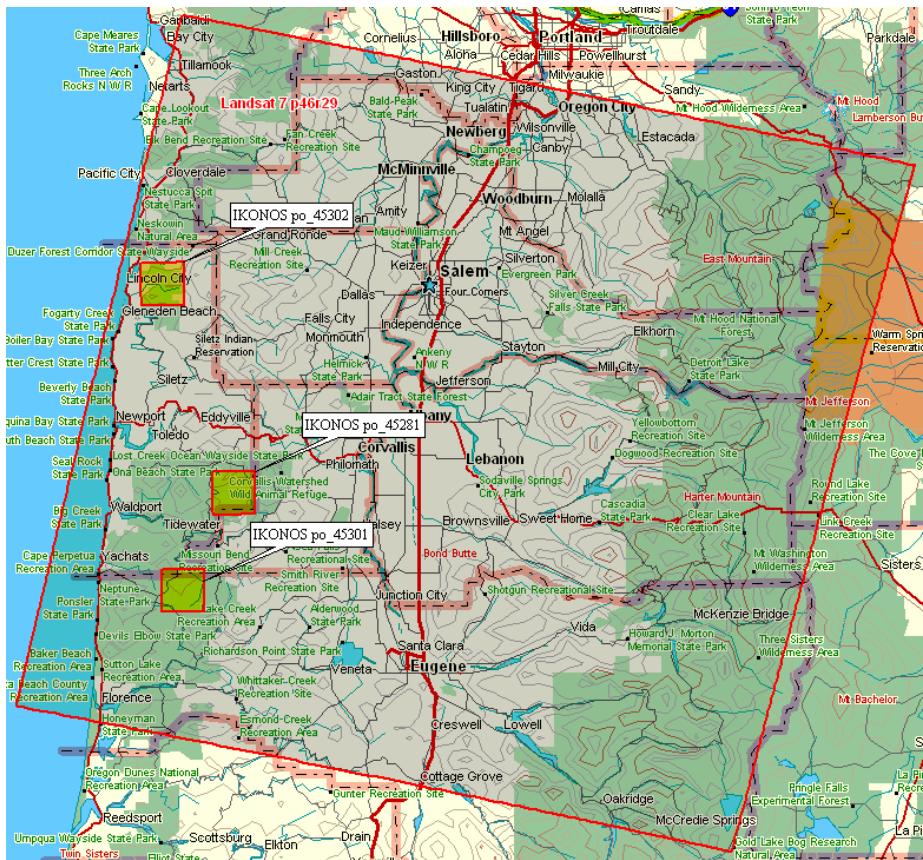


# Image Overlap: Oregon

Stennis Space Center

Images acquired on August 8, 2000

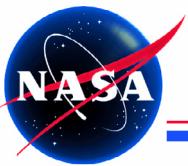
- IKONOS  
po\_45281 19:13 UTC 4 m GSD
- Landsat 7  
p46r29 18:47 UTC 30 m GSD



Both image products in map (north up) orientation

## Geolocation difference

Band 1:	47 m	[ 45.00, -15.00 ]
Band 2:	51 m	[ 48.75, -15.00 ]
Band 3:	47 m	[ 45.00, -15.00 ]
Band 4:	47 m	[ 45.00, -15.00 ]

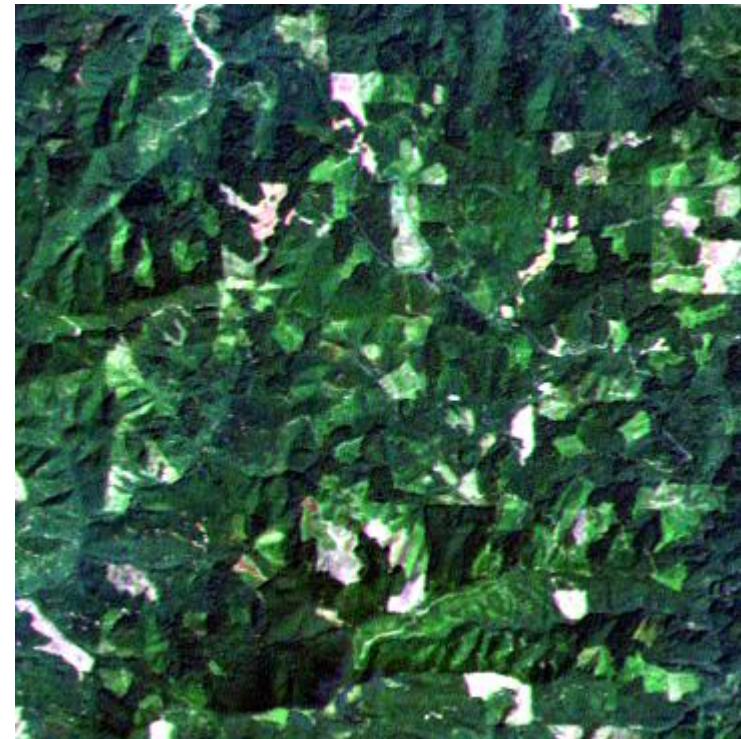


# Image Comparison: Oregon

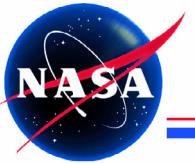
Stennis Space Center



Actual Landsat 7 image



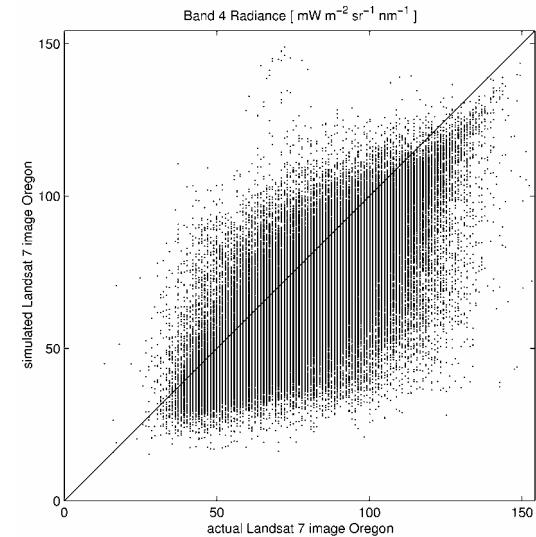
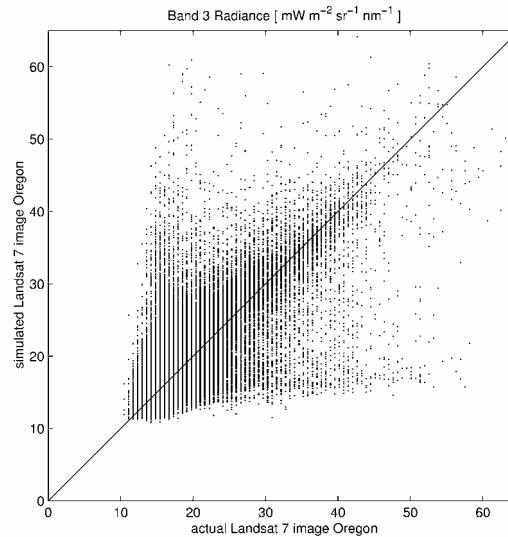
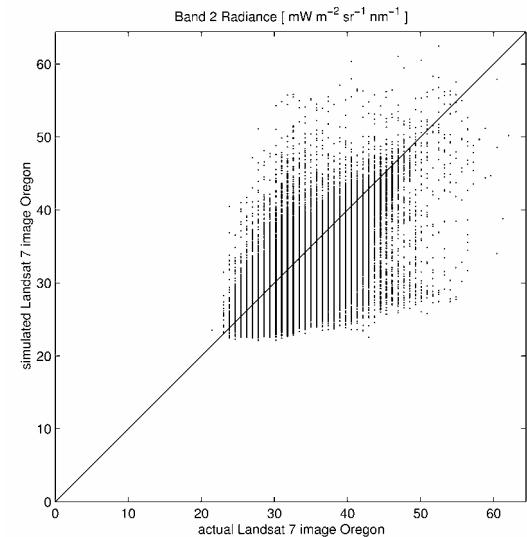
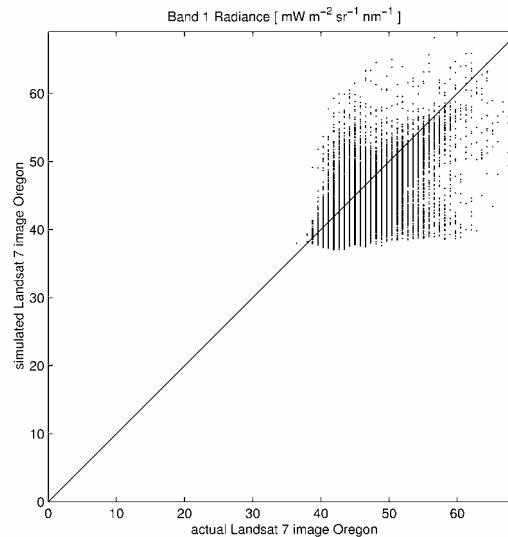
Simulated Landsat 7 image

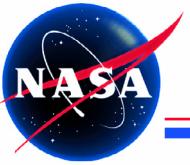


# Radiometric Comparison: Oregon

Stennis Space Center

Local differences in pixel geolocation create characteristic dispersion in the scatter plots





# Final Remarks

Stennis Space Center

- IKONOS images can be accurately transformed to mimic VNIR image data created by Landsat 7
- Mitigation of effects created by differences in acquisition time (solar angle), collection geometry (azimuth and elevation angle), and spectral response may be needed to achieve the accurate results
- The simulations become less accurate when atmospheric conditions are different (clouds) or when terrain relief creates local geolocation differences